Criteria for Establishing Zero Levels of Radioactive Content

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Statistical Applications

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Introduction:

This report recommends criteria by which materials can be judged to have zero levels of radioactive content. Background radiation and measurement error make such determination difficult, and criteria used must be able to withstand audit scrutiny. The criteria recommended require the selection of a critical value based on the costs and impacts of the potential misclassifications of the radioactive content. When approximate 95 percent confidence intervals based on a measurement contain zero but not the critical value, the material tested is taken to have zero radioactive content. Applications to waste oils and recovered silver are included.

Discussion:

Measurement of radioactive content is assumed to be reported in the form:

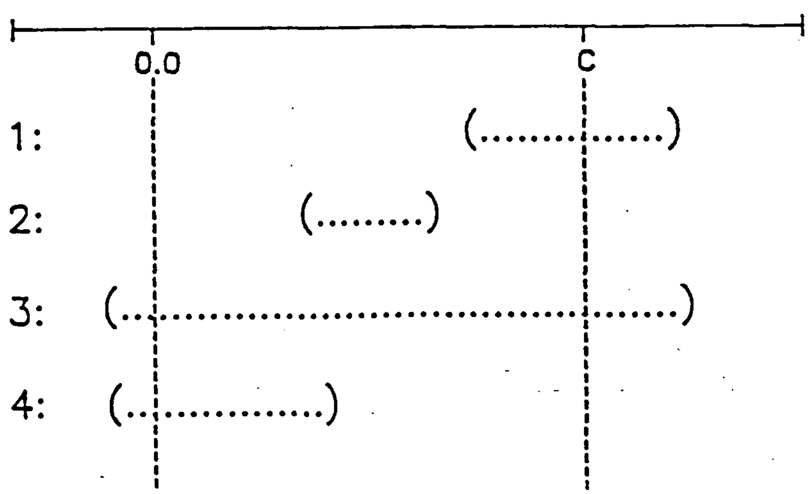
Measurement +/- Error

The error term is taken to be an approximate two sigma (95 per cent) estimate of the measurement uncertainty. An approximate 95 percent confidence interval is then obtained by computing an interval by adding and subtracting the error given from the measurement. For example, if a test result is received as .007 +/- .004, the resulting interval is (.003,.011).

Note this approach assumes approximate normality in the measurement method. If a particular measurement system shows significant departures from this situation, consideration should be given to making appropriate transformations of the data before applying of the criteria.

When such intervals are computed and compared to zero and a pre-selected critical value, four cases can arise as illustrated in Figure 1 below and discussed on the following page.

Figure 1: Zero Determination Cases



Case 1: Critical value is included while zero is not.

Case 2: Neither zero nor the critical value is included.

Case 3: Both zero and the critical value are included.

Case 4: Zero is included while the critical value is not.

The convention recommended is that in cases 1 and 2, since zero is not considered a reasonable result relative to the measurement obtained and the measurement error, the material tested is not assumed to have zero radioactive content. In case 3 when both values are included, the conservative approach of still not assuming zero radioactive content is recommended. Only in case 4 when zero is a possible value, and the critical value is not, will radioactive content be taken to be zero.

The critical value used should be selected relative to the degree of protection sought and the impact and cost of wrong decisions in either direction. That is, the impact and cost of handling material as having significant low-level radioactive content when is does not, or the impact and cost of dispositioning material as having no radioactive content when in fact it does.

Applications:

The first application of the criteria involves the radioactive content of waste oils. Oil with zero radioactive content (relative to background and measurement error) would be shipped for local incineration; other oil would be treated as low-level radioactive waste.

A reasonable estimate of the measurement error on oil that has no radioactive content has been demonstrated to be at least .004 pCi/g. This error estimate is used to generate the first of the two plots at the end of this report. The plot can be used to assist in selecting an appropriate critical value with which to apply the criteria.

The horizontal axis is the true radioactive content in pCi/g above background of oil. The vertical axis is the probability with respect to measurement error that such oil would be declared as having no radioactive content using the criteria given. The probabilities assume normality of the measurement data with error .004 (sigma = .002). Note that larger realized measurement error would in fact result in increased likelihood of not declaring zero content. The measurement error is not expected to be less than .004. The four curves represent the probabilities for potential critical values .006, .008, .010, and .012 respectively.

The table on the following page contains the values plotted. "Radioactivity" is the underlying radioactive content in pCi/g while P6 through P12 are the resulting probabilities for the four potential critical values.

Oil Radioactive Content Application

Radioactivity	P6	P8	P10	P12
-.004	1.00	1.00	1.00	1.00
-.003	0.99	1.00	1.00	1.00
-.002	0.98	1.00	1.00	1.00
-.001	0.93	0.99	1.00	1.00
.000	0.84	0.98	1.00	1.00
.001	0.69	0.93	0.99	1.00
.002	0.50	0.84	0.98	1.00
.003	0.31	0.69	0.93	0.99
.004	0.16	0.50	0.84	0.98
.005	0.07	0.31	0.69	0.93
.006	0.02	0.16	0.50	0.84
.007	0.01	0.07	0.31	0.69
.008	0.00	0.02	0.16	0.50
.009	0.00	0.01	0.07	0.31
.010	0.00	0.00	0.02	0.16
.011	0.00	0.00	0.01	0.07
.012	0.00	0.00	0.00	0.02

For each of the critical values, almost no oil found less than background (negative values) would be declared to not have zero radioactive content and thus not be shipped. Also for oil with content .12 pCi/g or greater, almost no oil would be declared at the zero radioactive level and thus be shipped.

As an example of the intermediate values, consider an underlying radioactivity level of .005. The four candidate critical values from .006 to .012 result in probabilities .07, .31, .69, and .93 respectively of declaring zero oil content. These tabled values and the corresponding plot should thus be used to select the critical value providing the most reasonable compromise of balancing the impacts and costs of the respective errors which can be made.

The second application is the radioactive content of silver recovered from various plant processes. Destinations to which the silver is shipped depend on such content. The second plot contains the analogous information for this application. Based on observed measurement data, the error is now assumed to be .1 (sigma = .05). Actual measurement error results would rarely be less than this. Tabled values are given on the following page. Similar use can be made of the values as in the first application.

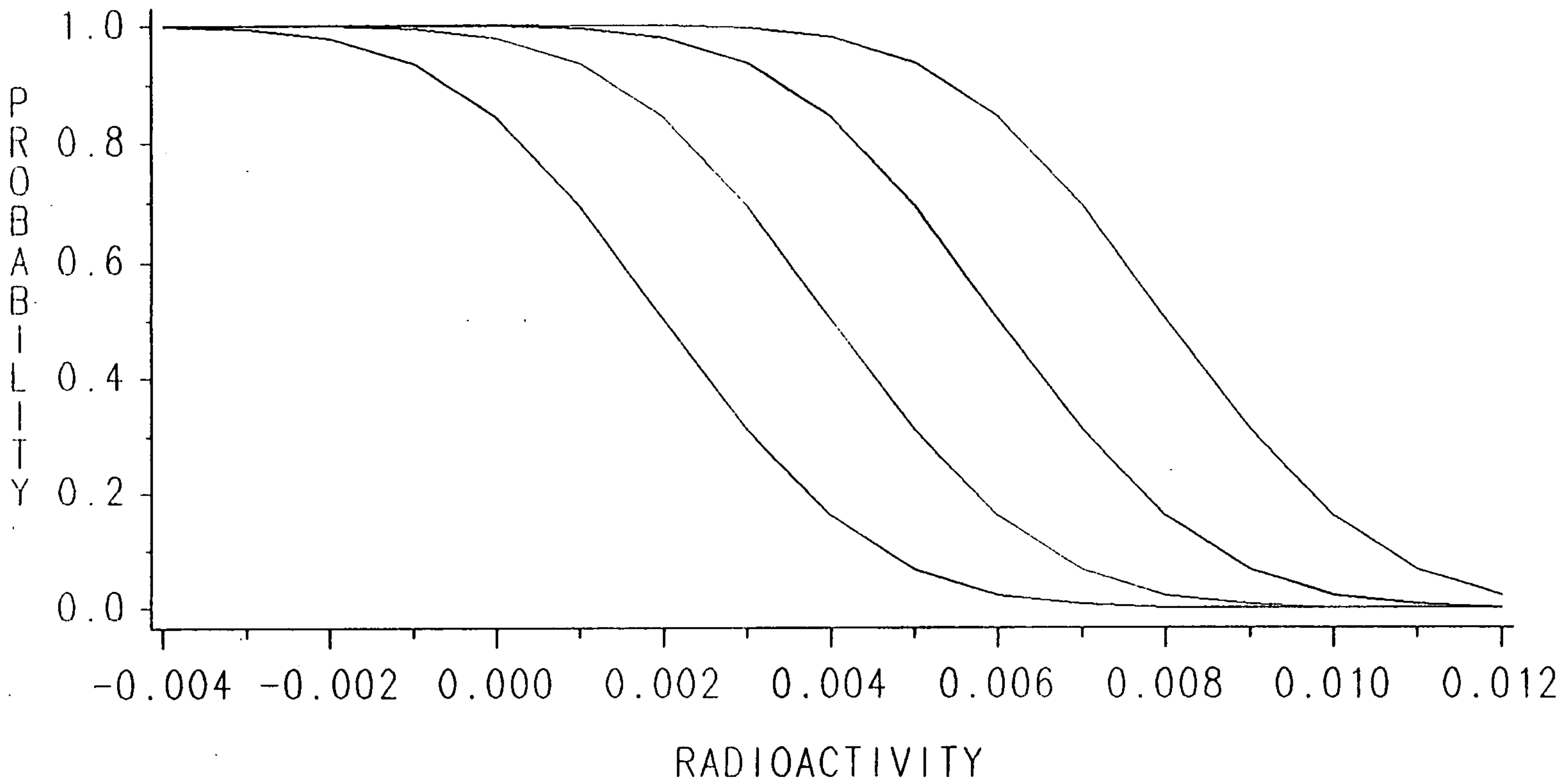
Note that in each application the critical values were taken to be three, four, five, and six times the minimum sigma value expected. This convention should be useful for other applications with the particular option chosen being dependent on the costs and impacts of the potential errors as discussed.

Silver Radioactive Content Application

Radioactivity	P15	P20	P25	P30
-.10	1.00	1.00	1.00	1.00
-.08	1.00	1.00	1.00	1.00
-.06	0.99	1.00	1.00	1.00
-.04	0.96	1.00	1.00	1.00
-.02	0.92	0.99	1.00	1.00
.00	0.84	0.98	1.00	1.00
.02	0.73	0.95	0.99	1.00
.04	0.58	0.89	0.96	1.00
.06	0.42	0.79	0.92	1.00
.08	0.27	0.66	0.84	0.99
.10	0.16	0.50	0.73	0.98
.12	0.08	0.35	0.58	0.95
.14	0.04	0.21	0.42	0.89
.16	0.01	0.12	0.27	0.79
.18	0.00	0.06	0.16	0.66
.20	0.00	0.02	0.08	0.50
.22	0.00	0.01	0.04	0.35
.24	0.00	0.00	0.01	0.21
.26	0.00	0.00	0.00	0.12
.28	0.00	0.00	0.00	0.06
.30	0.00	0.00	0.00	0.02

Probabilities of Shipping Oil Waste

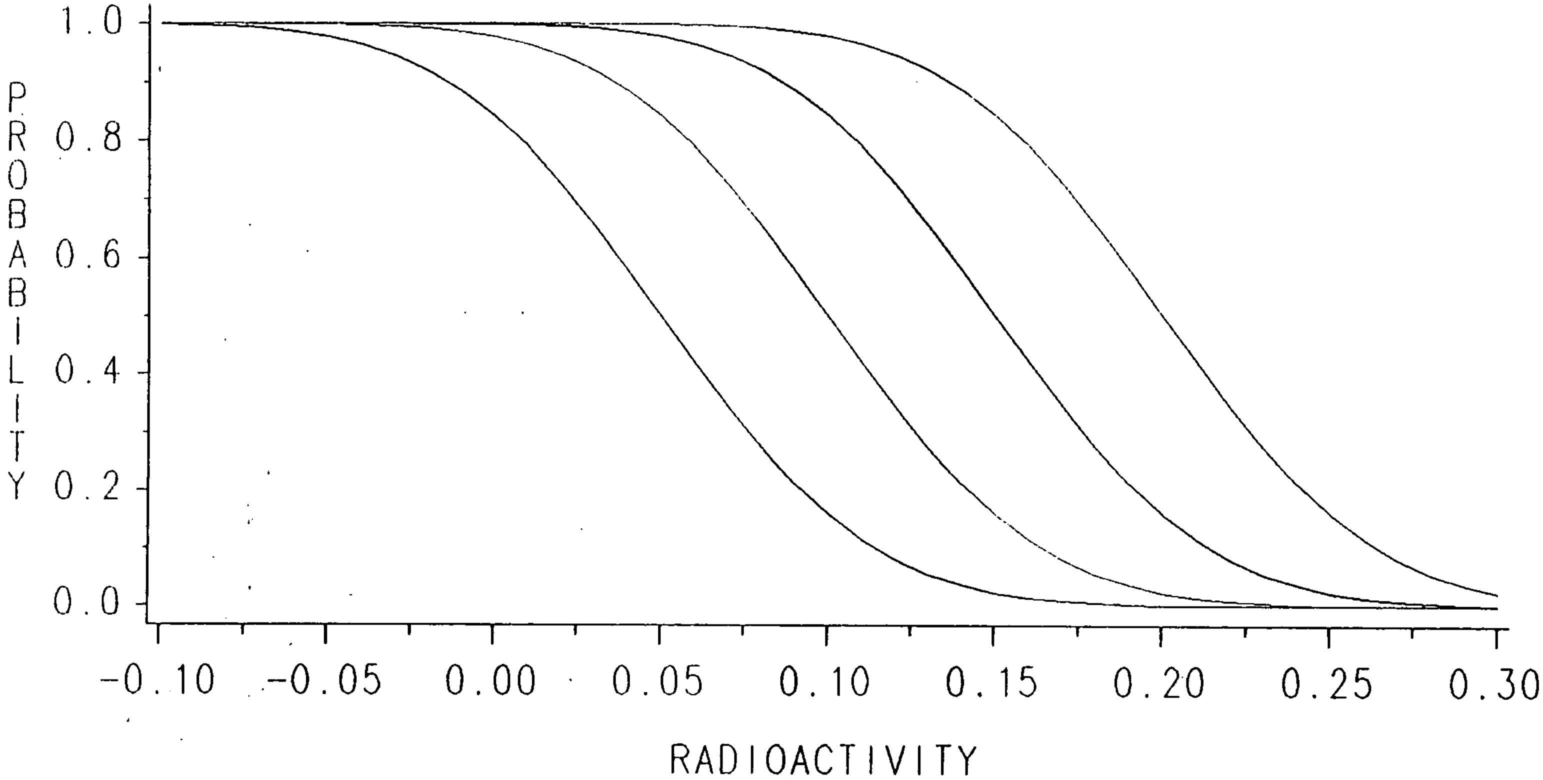
(assumes sigma = .002)



Units are pCi/g.
Curves from bottom to top are for critical values .006, .008, .010, and .012.

Probabilities of Silver Found Contaminated

(assumes sigma = .05)



Units are pCi/g.
Curves from bottom to top are for critical values .15, .20, .25, and .30.